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Effect of Diet With and Without Exercise Training on Markers of Inflammation and Fat Distribution in Overweight Women

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Abstract

The independent effects of exercise and weight loss on markers of inflammation (MOI) in obese individuals have not been clearly characterized. The objectives of this study were to: (i) identify the independent effects of exercise and weight loss on MOI and (ii) determine whether changes in MOI were associated with changes in fat distribution. Subjects were 126 healthy, premenopausal women, BMI 27–30 kg/m². They were randomized to one of three groups: diet only, diet + aerobic-, or diet + resistance training until a BMI <25 kg/m² was achieved. Fat distribution was measured with computed tomography, and body composition with dual-energy X-ray absorptiometry. Serum concentrations of tumor necrosis factor (TNF)- α , soluble TNF receptor 1 (sTNF-R1), soluble TNF receptor 2 (sTNF-R2), C-reactive protein (CRP), and interleukin (IL)-6 were assessed. Results of repeated-measures ANOVA indicated a significant effect of time on MOI, such that MOI decreased with weight loss. Results of mixed-model analysis indicated that adjusting for intra-abdominal adipose tissue (IAAT) and total fat mass explained the decreases in TNF- α and sTNF-R1, whereas only total fat mass explained the decreases in sTNF-R2, IL-6, and CRP. In conclusion, weight loss was associated with decreases in MOI. The effect of weight loss appeared to be mediated by changes in total fat mass or IAAT. Addition of exercise did not alter the response, suggesting that weight loss has a more profound impact for reducing MOI in overweight women than exercise.

INTRODUCTION

The prevalence of obesity has dramatically increased world-wide among both children and adults in recent years (1,2). Obesity is associated with the development of several chronic diseases, including metabolic syndrome, type 2 diabetes, cardiovascular diseases, cancer, and arthritis (3). Low-grade chronic inflammation is one of the key metabolic alterations linked with excessive caloric intake and adiposity (4). Tumor necrosis factor- α (TNF- α), interleukin-6 (IL-6), and C-reactive protein (CRP) are known to contribute to the development of atherosclerosis and insulin resistance (5,6). Therefore, it is important to identify both pharmacological and behavioral therapeutic interventions to reduce obesity-associated low-grade chronic inflammation.

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DISCLOSURE

The authors declared no conflict of interest.

Although several studies have shown that markers of inflammation (MOI) are reduced following dietary weight loss (7–9), it is not clear if the effect of weight loss is due to loss of fat mass specifically. The majority of investigations have used BMI as an index of body composition (10,11). Because BMI is not an accurate measure of body composition, studies are needed that evaluate changes in fat mass and lean mass in conjunction with changes in inflammation with weight loss. Furthermore, it is not clear if the beneficial effects of weight loss are the result of selective loss of particular adipose tissue depots. Visceral fat in particular is thought to be associated with inflammation, whereas subcutaneous fat may be a “metabolic sink” that prevents accumulation of visceral fat and thereby limits inflammation (12). It is believed when the subcutaneous fat depot becomes overwhelmed there is greater accumulation of visceral fat, which is associated with cardiovascular disease (13), the metabolic syndrome (14), and circulating levels of IL-6, TNF- α , and CRP (13,15). Therefore, determining whether changes in specific adipose depots are associated with reductions in inflammation, and identifying strategies to reduce these depots, may be essential for reducing circulating MOI.

In addition to weight loss, physical activity may be effective in reducing inflammation. Data from observational studies show that greater physical activity is associated with lower MOI (11,16,17). However, few studies have looked at long-term exercise interventions and the associated changes in MOI. Studies that have looked at the effect of long-term exercise interventions on changes in MOI have included weight loss (11,16,17). As discussed above, weight loss decreases MOI (7–9), making it difficult to identify the independent effect of the exercise component.

Therefore, the objective of this study was to identify the independent effects of body composition, fat distribution, and exercise (aerobic or resistance training) on MOI in women who participated in a hypocaloric weight loss intervention. Specific measures of fat distribution examined were intra-abdominal adipose tissue (IAAT), superficial subcutaneous adipose tissue, and deep subcutaneous adipose tissue.

METHODS AND PROCEDURES

Subjects

Subjects were 213 healthy, overweight, premenopausal women who volunteered for, and enrolled in, an ongoing study designed to examine metabolic factors that predispose women to weight gain. The sample size included in this study was 126 women from the previously mentioned parent study. is sample size included those subjects who adhered to the diet and exercise requirements of the parent study. In total, 83 subjects dropped out of the study during the intervention, and plasma samples were not available for four subjects. Inclusion criteria for the parent study were BMI 27–30 kg/m², premenopausal, age 20–41 years, sedentary (no more than one time per week regular exercise), normal glucose tolerance, family history of overweight/obesity in at least one first-degree relative, and no use of medications that affect body composition or metabolism. All women were nonsmokers and reported experiencing menses at regular intervals. The study was approved by the institutional review board for Human Use at the University of Alabama at Birmingham (UAB). All women provided informed consent before participating in the study.

Study design

Subjects were evaluated in the overweight state (prior to any intervention). Weight was stabilized for 4 weeks through dietary control. All testing was conducted following the weight stabilization period, and in the follicular phase of the menstrual cycle. During the weight stabilization period, body weights were measured three to five times per week at the

General Clinical Research Center (GCRC) at UAB. A macronutrient-controlled diet was provided during the final 2 weeks of weight maintenance. The energy content was appropriately adjusted to ensure a stable body weight ($\leq 1\%$ variation from initial body weight). All diets consisted of $\sim 22\%$ of energy from fat, 23% from protein, and 55% from carbohydrate.

Subjects were then randomized to one of three intervention groups: diet only, diet + aerobic training, and diet + resistance training. After discharge from the initial GCRC in-patient visit, the GCRC kitchen provided all meals for the period of weight reduction. Subjects were provided a 3,350 kJ (800 kcal) diet, which was designed to meet all nutrient requirements excluding energy requirements. Subjects were maintained on the diet and/or aerobic or resistance training until a BMI < 25 was achieved. Having attained a normal body weight, subjects then repeated the 4-week protocol of energy balance followed by the 4-day admission and evaluation at the GCRC.

Briefly, subjects assigned to the exercise groups participated in three supervised training sessions each week throughout the study. Sessions lasted ~ 50 min and took place in exercise rooms in the Bell Training Facility or in the exercise facility in the nursing building on the UAB campus. Aerobic training included three sessions per week of walking/ running on a treadmill, starting at 65% of maximum heart rate for 20 min. Exercise intensity and duration were gradually increased until subjects exercised at 80% of maximum heart rate for 40 min at week 8. Resistance training included three sessions per week of 10 exercises (leg press, squats, leg extension, leg curl, elbow flexion, lateral pull-down, bench press, military press, lower back extension, and bent leg sit-ups). One set of 10 repetitions per exercise was completed during the first 4 weeks, after which two sets were performed. Sixty percent of the maximum weight that could be lifted one time (1 RM) was used during the 1st week and intensity was gradually increased so that 80% of 1 RM was used by the 4th week and continued throughout the remainder of the study. Subjects on the exercise interventions were evaluated an average of 48–72 h after the last exercise bout.

Body composition and fat distribution

Total and regional body composition, including total fat mass, percent body fat, leg fat mass, and lean body mass were measured by dual-energy X-ray absorptiometry (Prodigy; Lunar Radiation, Madison, WI). The scans were analyzed with the use of ADULT software, version 1.33 (Lunar Radiation). IAAT and subcutaneous abdominal adipose tissue were analyzed by computed tomography scanning (18,19) with a HiLight/Advantage Scanner (General Electric, Milwaukee, WI) located in the UAB Department of Radiology. Subcutaneous abdominal adipose tissue was further subdivided into superficial and deep compartments (20). Subjects were scanned in the supine position with arms stretched above their heads. A 5-mm scan at the level of the umbilicus (approximately the L4–L5 intervertebral space) was taken. Scans were analyzed for cross-sectional area (cm^2) of adipose tissue using the density contour program with Hounsfield units for adipose tissue set at -190 to -30 . All scans were analyzed by the same individual. The coefficient of variation (CV) for repeat cross-section analysis of scans among 40 subjects in our laboratory is $< 2\%$ (19).

Laboratory analyses

All analyses were conducted in the Core Laboratory of UAB's GCRC, Diabetes Research Training Center, and Nutrition and Obesity Research Center. Glucose was measured using an Ektachem DT II System (Johnson and Johnson Clinical Diagnostics, Rochester, NY). In the core laboratory, this analysis has a mean intra-assay CV of 0.61%, and a mean inter-assay CV of 2.56%. Insulin was assayed in duplicate 100- μl aliquots using double-antibody

radioimmunoassay (Linco Research, St Charles, MO). In the core laboratory, this assay has a sensitivity of 3.35 μ IU/ml, a mean intra-assay CV of 3.49%, and a mean interassay CV of 5.57%. MOI were assessed using enzyme-linked immunosorbent assays (ELISAs). All samples were analyzed in duplicate. TNF- α was analyzed using the high-sensitivity ELISA kit (Quantikine HSTA00C; R&D Systems, Minneapolis, MN). Four TNF- α values were below the minimum detectable concentration (0.50 pg/ml); these samples were assigned the value of the minimum detectable concentration. sTNF-R1 was measured with the EASIA ELISA kit (KAC1761; Invitrogen, Carlsbad, CA). sTNF-R2 was measured with the EASIA ELISA kit (KAC1771; Invitrogen). IL-6 was assayed using the high-sensitivity ELISA kit (Quantikine HS600B; R&D Systems). CRP was assayed with the high-sensitivity ELISA kit (030-9710s; ALPCO, Windham, NH). CRP concentrations >10 mg/l represent an acute state of inflammation (21); therefore all values of CRP >10 mg/l were omitted from analyses (this affected 16 values).

Statistical analysis

Descriptive statistics were computed for each treatment group (diet only, diet/aerobic, and diet/resistance) at baseline and following weight loss. All values are reported as means $\pm$ s.d. All statistical models were evaluated for residual normality and logarithmic transformations were performed when appropriate. All data were analyzed using SAS (version 9.1; SAS Institute, Cary, NC).

Comparisons between baseline and the weight-reduced state were performed using the two-group *t*-test. Overall comparisons of the change in fat depots and MOI by intervention group were performed using repeated-measures ANOVA. Repeated-measures mixed-models analyses were used to evaluate changes in MOI after weight loss. Independent variables included in these models were time, total fat mass, and IAAT. For all analyses, a *P* value <0.05 was deemed statistically significant. There were no significant differences in any of the models after adjusting for superficial subcutaneous adipose tissue and deep subcutaneous adipose tissue, therefore they were not included in the final analysis.

RESULTS

Descriptive statistics are shown in Table 1. At baseline body weight, BMI, fat distribution, and MOI were not significantly different between groups. All MOI and adiposity measures significantly decreased with weight loss Table 1.

The effects of intervention group, time, and intervention group $\times$ time interactions on all variables are shown in Table 2. A significant time effect was observed on all variables, with the exception of lean mass. *Post-hoc* analysis revealed no between group differences for time effect for any of the TNF system markers. However, *post-hoc* analysis showed a significant time effect in the resistance group for IL-6 and a significant time effect for diet only and resistance group for CRP. There was no effect of intervention group on any MOI. However, there was a significant intervention group $\times$ time interaction seen in lean body mass with weight loss, such that resistance trained women had a small but significant increase in lean mass compared to no change in the other interventions.

Results from mixed modeling for the TNF system are displayed in Table 3. In mixed modeling for TNF- α , soluble tumor necrosis factor receptor 1 (sTNF-R1), and soluble tumor necrosis factor receptor 2 (sTNF-R2), there was a significant time term, indicating that the TNF system decreased with weight loss. Adjusting for the change in IAAT and total fat mass explained the decreases in TNF- α and sTNF-R1 with weight loss, however, only change in total fat mass explained the decrease in sTNF-R2.

Results from mixed modeling for IL-6 and CRP are displayed in Table 4. A significant time effect was found in both IL-6 and CRP. Adjusting for the change in IAAT did not explain the decrease in IL-6 or CRP with weight loss. Total fat mass explained the change in both IL-6 and CRP following weight loss. Furthermore, total fat mass not only explained the change in IL-6 with weight loss, it was independently associated with change in IL-6.

DISCUSSION

The purpose of this study in healthy overweight premenopausal women was to identify the independent effects of energy restriction alone and energy restriction in combination with exercise on changes in MOI, and whether these changes were associated with changes in body composition or regional fat distribution. The main findings were that: (i) weight loss was associated with significant decreases in MOI; (ii) the addition of aerobic or resistance exercise to the energy restriction paradigm did not alter the outcome; and (iii) the decrease in MOI were strongly associated with changes in IAAT and total fat mass. These observations suggest that regardless of weight loss method (with or without exercise), loss of total and/or intra-abdominal fat mass was most strongly associated with improvements in inflammatory status.

Chronic inflammation is an important cause of cardiovascular disease, and is strongly associated with obesity and metabolic dysfunction (22,23). Current literature suggests that adipose tissue macrophage density increases with obesity, reducing production of anti-inflammatory adipokines, and increasing secretion of proinflammatory cytokines (24,25). Several studies have documented that weight loss in conjunction with energy restriction (7–9,26), surgery (27), or exercise (16,28) can improve both body composition and MOI. However, the independent effects of energy restriction and exercise on MOI have not been well documented. Prior investigations have not provided a clear picture; studies have shown that exercise training induces improvements in inflammation independent of BMI (11,29,30) and others that suggest weight loss-associated reductions in inflammation are independent of exercise (10,31). The lack of a control group (diet only) in the majority of these studies has been a major limitation when trying to identify the independent effects of exercise on inflammation (11,29,32).

In this study, we utilized a diet-only control group in conjunction with diet/aerobic- and diet/resistance exercise training groups in order to determine whether the addition of exercise to a weight-reducing diet would result in greater improvements in MOI and body composition compared to a weight-reduced diet alone. Our mixed-model analysis revealed no effect of intervention group (diet only, diet/aerobic, or diet/resistance) on MOI (Table 2), suggesting that the intervention type was not independently related to decreases in inflammation with weight loss. Instead, time was a significant predictor in all models, suggesting that weight loss was primarily responsible for the decrease in MOI (Tables 3 and 4). This is in agreement with the two other sufficiently powered-randomized clinical trials that examined the independent effects of exercise and weight loss on MOI in a cohort of men and women (10,33). Both studies found no independent effect of exercise on MOI. Furthermore, when taking into account differences in study designs, it appears that when exercise interventions are used independently (without diet) there are significant improvements in inflammation (30,34). However, when exercise is incorporated with dietary weight loss (10) or exercise training is performed without any significant weight loss (31,35) the exercise effect is reduced or lost completely. us, it appears that the effect of exercise on MOI is primarily due to reductions of fat mass rather than a specific effect of exercise alone.

This study was also designed to more closely examine the relationship between changes in body composition with MOI. It has previously been shown that changes in IL-6 and CRP

were independent of changes in BMI (10). However, the use of BMI is a limitation because BMI is not a measure of body composition or fat distribution. Body composition measures alone do not differentiate between specific fat depots, therefore prior investigations were unable to assess independent associations between inflammation and fat distribution. The present study utilized dual-energy X-ray absorptiometry and computed tomography imaging to examine the influence of fat distribution on MOI. It has been well documented that IAAT is associated with elevated MOI (13,15). Our results are in agreement with this, as we found that decreased MOI (IL-6, CRP, TNF- α , sTNF-R1, and sTNF-R2) following weight loss could be explained by total fat mass and/or IAAT (Tables 3 and 4). Therefore, within our population of premenopausal women, MOI were linked with adiposity.

It has been well documented that a negative energy balance generated from either exercise or diet elicits a very potent anti-inflammatory effect (7,8,28,36). The majority of these studies obtained postweight loss measurements while the subjects were still in negative energy balance, making it difficult to identify the independent effects of the diet and/or exercise-induced changes in body composition or anti-inflammatory effects of contracting skeletal muscle from the effects of negative cellular energy balance. It seems plausible that once the participants in these studies reestablished energy balance, the inflammatory profile may return to preintervention levels. In order to eliminate the potential confounding effects of negative energy balance on MOI, we incorporated a 4-week postweight loss intervention diet in order to obtain an energy-balanced state before blood sampling. Therefore, we are able to conclude that changes in MOI in this study were due to reductions in total fat mass and/or IAAT not negative energy balance. It appears that decreasing adiposity from diet and/or exercise is an effective means for reducing circulating MOI.

Strengths of this study included robust measures of body composition and body fat distribution. Postweight loss measures were taken after participants were placed on a 4-week diet, which was designed to ensure an energy-balanced state (eliminating the potential independent effects of negative energy balance on metabolic outcomes). Further strengths of the study were the inclusion of a dietary control group in conjunction with diet/exercise groups enabled us to assess the independent and combined effects of diet and exercise. A limitation in this study was the absence of an exercise group that did not lose weight. Based on previous studies (11,16,17) it is very possible that exercise by itself may have had a positive affect on cytokines. Further studies are needed to separate the independent effects of weight loss vs. exercise. Additionally, our results are limited to a population of healthy, overweight, premenopausal women. Similar studies on men, obese individuals, children, and post-menopausal women would be of interest.

In conclusion, the overall implication from the present study was that loss of total and visceral fat was the biggest contributor to decreases in circulating MOI with weight loss, and that resistance and aerobic exercise training did not have a further independent effect on inflammation. Further research is needed to examine the potential differences between anti-inflammatory cytokines that may be released from skeletal muscle during exercise and proinflammatory cytokines associated with adiposity, immune dysfunction, and chronic diseases.

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Table 1

Body composition and markers of inflammation with weight loss

(n = 126)	Baseline	Weight reduced	P
Body weight (kg)	78 ± 8 ^a	66 ± 7 ^b	0.001
BMI (kg·m ⁻²)	28 ± 3 ^a	24 ± 1 ^b	0.001
Fat mass (kg)	33 ± 5 ^a	22 ± 5 ^b	0.001
Body fat (%)	45 ± 4 ^a	35 ± 5 ^b	0.001
Lean mass (kg)	41 ± 4 ^a	41 ± 4 ^a	0.776
IAAT (cm ²)	80 ± 32 ^a	51 ± 25 ^b	0.001
SSAAT (cm ²)	193 ± 50 ^a	133 ± 48 ^b	0.001
DSAAT (cm ²)	141 ± 53 ^a	86 ± 37 ^b	0.001
TNF- α (pg/ml)	1.06 ± 1.01 ^a	0.92 ± 0.72 ^b	0.049
sTNF-R1 (ng/ml)	1.81 ± 0.38 ^a	1.76 ± 0.35 ^b	0.007
sTNF-R2 (ng/ml)	4.02 ± 1.09 ^a	3.79 ± 0.93 ^b	0.003
IL-6 (pg/ml)	1.81 ± 1.32 ^a	1.34 ± 0.73 ^b	0.001
CRP (mg/l)	3.12 ± 0.44 ^a	2.89 ± 0.43 ^b	0.001

All data are presented as means ± s.d. Results from paired sample *t*-test; means with different superscripts are significantly different ($P < 0.05$). The boldface values depict statistical significance between variables (derived from paired sample *t*-tests.)

CRP, c-reactive protein; DSAAT, deep subcutaneous abdominal adipose tissue; IAAT, intra-abdominal adipose tissue; IL-6, interleukin-6; SSAAT, superficial subcutaneous abdominal adipose tissue; sTNF-R1, tumor necrosis factor receptor 1; sTNF-R2, tumor necrosis factor receptor 2; TNF- α , tumor necrosis factor- α

Table 2

Body composition and markers of inflammation with weight loss by intervention group

	Diet (n = 29)		Aerobic (n = 43)		Resistance (n = 54)		G × T	
	Baseline	Weight reduced	Baseline	Weight reduced	Baseline	Weight reduced	G	T
Body weight (kg)	78 ± 8 ^a	66 ± 7 ^b	77 ± 7 ^a	65 ± 6 ^b	78 ± 8 ^a	66 ± 7 ^b	0.628	0.001
BMI (kg.m ²)	28 ± 1 ^a	24 ± 1 ^b	28 ± 1 ^a	24 ± 1 ^b	28 ± 1 ^a	24 ± 1 ^b	0.853	0.001
Fat mass (kg)	33 ± 6 ^a	22 ± 5 ^b	34 ± 5 ^a	22 ± 5 ^b	33 ± 5 ^a	22 ± 4 ^b	0.967	0.001
Body fat (%)	44 ± 4 ^a	35 ± 5 ^b	46 ± 4 ^a	35 ± 5 ^b	45 ± 4 ^a	34 ± 4 ^b	0.416	0.001
Lean mass (kg)	41 ± 4 ^a	41 ± 4 ^a	40 ± 4 ^a	40 ± 4 ^a	41 ± 4 ^a	42 ± 4 ^b	0.079	0.568
IAAT (cm ²)	93 ± 35 ^a	58 ± 26 ^b	79 ± 31 ^a	48 ± 21 ^b	77 ± 31 ^a	53 ± 31 ^b	0.227	0.001
SSAAT (cm ²)	183 ± 49 ^a	127 ± 54 ^b	205 ± 55 ^a	140 ± 55 ^b	189 ± 45 ^a	140 ± 40 ^b	0.348	0.001
DSAAT (cm ²)	137 ± 55 ^a	86 ± 38 ^b	149 ± 52 ^a	77 ± 33 ^b	135 ± 52 ^a	93 ± 38 ^b	0.975	0.001
TNF-α (pg/ml)	1.15 ± 1.71 ^a	0.81 ± 0.50 ^a	1.11 ± 1.00 ^a	0.94 ± 0.74 ^a	0.98 ± 0.73 ^a	0.97 ± 0.80 ^a	0.785	0.001
sTNF-R1 (ng/ml)	1.86 ± 0.34 ^a	1.83 ± 0.26 ^a	1.80 ± 0.38 ^a	1.73 ± 0.35 ^a	1.79 ± 0.40 ^a	1.73 ± 0.39 ^a	0.404	0.021
sTNF-R2 (ng/ml)	3.94 ± 0.77 ^a	3.83 ± 0.66 ^a	4.15 ± 1.11 ^a	3.82 ± 0.91 ^a	3.95 ± 1.21 ^a	3.74 ± 1.06 ^a	0.644	0.003
IL-6 (pg/ml)	1.71 ± 1.17 ^{ab}	1.27 ± 0.65 ^{ab}	1.82 ± 1.27 ^{ab}	1.38 ± 0.59 ^{ab}	1.85 ± 1.46 ^a	1.34 ± 0.86 ^b	0.724	0.001
CRP (mg/l)	1.93 ± 1.64 ^{ab}	1.13 ± 1.23 ^c	1.91 ± 1.97 ^{abc}	1.59 ± 1.67 ^{abc}	2.20 ± 2.05 ^a	1.61 ± 1.94 ^{b,c}	0.653	0.001

All data are presented as means ± s.d. Far-right columns indicate results of repeated-measures ANOVA for main effects of group (G), time (T), and the group-by-time interaction (G × T). Within a row, results of *post-hoc* analyses among the three groups are provided with superscripts; means with different superscripts are significantly different (P < 0.05). The boldface values are indicative of G, T, or G × T effects that were statistically significant.

CRP, C-reactive protein; DSAAT, deep subcutaneous abdominal adipose tissue; G × T, group × time interaction; G, intervention group; IAAT, intra-abdominal adipose tissue; IL-6, interleukin-6; SSAAT, superficial subcutaneous abdominal adipose tissue; sTNF-R1, tumor necrosis factor receptor 1; sTNF-R2, tumor necrosis factor receptor 2; T, time; TNF-α, tumor necrosis factor-α.

Table 3Mixed models for TNF- α , TNF-R1, and TNF-R2 with weight loss ($n = 124$)

Model		Independent variable	<i>P</i>
1	TNF- α	Time	0.001
2		Time	0.252
		IAAT	0.388
3		Time	0.157
		Fat Mass	0.603
1	sTNF-R1	Time	0.010
2		Time	0.131
		IAAT	0.719
3		Time	0.461
		Fat Mass	0.104
1	sTNF-R2	Time	0.001
2		Time	0.018
		IAAT	0.884
3		Time	0.234
		Fat Mass	0.946

Boldface values indicate significant differences ($P < 0.05$). All variables adjusted for ethnicity.

IAAT, intra-abdominal adipose tissue; sTNF-R1, tumor necrosis factor receptor 1; sTNF-R2, tumor necrosis factor receptor 2; TNF- α , tumor necrosis factor- α .

Table 4Mixed models for IL-6 and CRP with weight loss ($n = 125$)

Model		Independent variable	<i>P</i>
1	IL-6	Time	<0.001
2		Time	0.006
		IAAT	0.202
3		Time	0.580
		Fat mass	0.036
1	CRP	Time	<0.001
2		Time	<0.001
		IAAT	0.850
3		Time	0.069
		Fat mass	0.617

Boldface values indicate significant differences ($P < 0.05$). All variables adjusted for ethnicity.

CRP, C-reactive protein; IAAT, intra-abdominal adipose tissue; IL-6, interleukin-6.